2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE) 978-1-7281-4142-8/20/$31.00 ©2020 IEEE 10.1109/ic-ETITE47903.2020.450

An IoT Based Smart Water Quality Monitoring System using Cloud

1st Ajith Jerom B
Department of CSE
PSG Institute of Technology and Applied Research
Coimbatore, India
ajith@psgitech.ac.in

2nd Manimegalai R
Department of CSE
PSG Institute of Technology and Applied Research
Coimbatore, India
drrm@psgitech.ac.in

3rd Ilayaraja V
Department of CSE
PSG Institute of Technology and Applied Research
Coimbatore, India
infoila11@gmail.com

Abstract— ***The Internet of Things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators and connectivity which enables these things to connect and exchange data. The number of IoT devices has increased 31% year-over-year to 8.4 billion in 2017 and it is estimated that there will be 30 billion devices by 2020. Water pollution is a major environmental problem in India. The largest source of water pollution in India is untreated sewage. Other sources of pollution include agricultural runoff and unregulated small scale industry that results in polluting, most of the rivers, lakes and surface water in India. In this paper, An IoT Based Smart Water Quality Monitoring System using Cloud and Deep Learningis proposedto monitor the quality of the water in water-bodies. In conventional systems, the monitoring process involves the manual collection of sample water from various regions, followed by laboratory testing and analysis. This process is ineffective, as this process is arduous and time-consuming and it does not provide real-time results. The quality of water should be monitored continuously, to ensure the safe supply of water from any water bodies and water resources. Hence, the design and development of a low-cost system for real-time monitoring of water quality using the Internet of Things (IoT) is essential. Monitoring water quality in water bodies using Internet of Things (IoT) helps in combating environmental issues and improving the health and living standards of all living things. The proposed system monitors the quality of water relentlessly with the help of IoT devices, such as, NodeMCU. The in-built Wi-Fi module is attached in NodeMCU which enables internet connectivity transfers the measured data from sensors to the Cloud. The prototype is designed in such a way that it can monitor the number of pollutants in the water. Multiple sensors are used to measure various parameters to assess the quality of water from water bodies. The results are stored in the Cloud, deep learning techniques are used to predict whether the water suitable or not.***

Keywords— ***Water Quality Monitoring, Internet of Things (IoT), ESP8266, Wi-Fi protocol, Firebase Cloud.***

I. INTRODUCTION

Wireless sensor networks are becoming popular among the research community for their low-costdesign and simple form factor. The latest advancements in wireless technology improve large field data acquisition and reliability in hostile environmental conditions. Moreover, the research community focuses on the form factor and expansion of the wireless node involving in remote process monitoring and automation.Internet of Things (IoT) is the combination of a physical object, controller, sensor, actuators, and Internet. IoT plays vital role in Industry 4.0. Actuators and sensors are the devices that interact with real-world physical objects and collect data from the environment. Actuators and sensors, process the electrical input and transform into tangible action. IoT devices collect a huge amount of data, that are valuable and useful which should be stored, organized and processed. The principal architecture of IoT is based on three layers: *i)*. Physical Layer, *ii)*.Network Layer, and *iii)*.Application Layer. In the physical layer, sensors measure the data from outside environment and turn into valuable data. After data collection, time-sensitive data need to be processed immediately. Otherwise, the data has to be deeply processed and analyzed to be stored in the Cloud to avoid network clutter. In the network layer, the raw data are collected from various sensors to be aggregated and converted to digital streams for data processing. For data processing, Data Acquisition System(DAS) [21] is the most suitable process to sample the signals from the real-world objects to convert the results into digital numeric values that can be manipulated with the computer. The working principle of data acquisition is to convert analog waves into digital values for data processing. Internet gateway receives the aggregated and digital data through Wi-Fi, WLANs, etc. The application layer delivers specific services to the user. Subsequently, the data can be safely stored in the server or Cloud for analysis. When IoT is augmented with sensors and actuators, the technology becomes a more general class of Cyber-Physical Systems (CPS), that also encompasses technologies such as smart grids, virtual power plants, smart homes, smart classrooms, intelligent transportation, smart hospital, smart traffic, and smart cities. IoT primarily exploits standard protocols and networking technologies. However, some of the major enabling technologies and protocols used in IoT are RFID, NFC, low-energy Bluetooth, low-energy wireless, low-energy radio protocols, LTE-A, and WiFi-Direct. Also, the chemical reagents costs are usually high that leads to an increase in the test cost. The researchers focus on developing a real-time water quality monitoring system to measure the solvent and pollutants in the water bodies and ensure real-time data acquisition to the database using the Internet of Things (IoT) for live water quality analysis.

978-1-7281-4142-8/$31.00 ©2020 IEEE

II. WATER QUALITY MONITORING

Environmental pollution is the main reason to measure and understand the toxic, chemical and biological quality parameters of water. Most of the water bodies are polluted by humans. Almost 71% of the Earth's surface is covered by water, and over 96% of water is saline in the oceans. Water seems to be one of the major resources for all the forms of life, including human beings, animals, plants, trees, birds, etc. on earth for survival. On Earth, only 2.5% of water is found to be fresh water. Albeit, 0.3% of freshwater is present in lakes, wells, rivers and dams. In a year, about 95% of the available freshwater are entering into drains from households [27]. Nearly, four gallons of water is getting wasted through leakage in taps and other domestic use. About 80% of water gets polluted because of industrial wastage which is dumped into lakes, rivers and buried under deep oceans without any proper treatment. A lot of toxic agents and chemicals are getting dissolved in freshwater thus making it highly contaminated. The people in rural areas do not have awareness about these contaminations. Around 70% of groundwater is being utilized for agricultural purposes in the world. It is expected that water demand is going to rise by 50% in the future. While using polluted water for agriculture, the land also is also polluted which causes serious harm for all the dependent living things [6]. As the water bodies pollute the land, it creates an imbalance in the environment biosphere. Any imbalance in the water will affect its quality that severely affects the ecological system among the species [5]. Most nuclear reactors wastage are sealed and buried under the ocean; if any leakage happens, the entire sea will become harmful and every living thing in the sea gets affected. During the 19^{th} century, water samples were collected from various places and and were tested in the laboratory. The results were astonishing [9]. A study by water aid estimated that 41% of people living in urban areas live without adequate sanitation. Nearly 80% percent of disease spread through polluted water. Some of the diseases won't reflect immediately, it will affect the inner organs of the living things and later cause serious effects. In some countries, lot of people do not have access to clean water due to lack of government prioritization, lack of dedicated funding, shortages in human resources and the exacerbating effects of climate change on water availability and quality [17]. There are approximately 101 principal parameters to check the water quality initiated by the environmental protection agency [24]. If any of the values crosses its parameter level then it is an imbalance in water and it is not suitable for domestic usage. To provide a viable and cost-effective solution to this problem, sensors are considered. With the help of sensors, a solution is offered that can considerably reduce the costs, as well as provide the capabilities to monitor the water quality uninterruptedly. There comes a lot of challenges to monitor the quality of water owing to human disaster, population growth and sudden changes in the environment. IoT becomes the era of sensing the environment continuously in real-time and able to provide accurate results. The use of automation for continuous monitoring reduces the manual power and thus reduces the cost too. This mechanism is being designed and developed with a low cost effective monitoring system for the principal parameters in real-time. In the proposed work, pH, Humidity, Temperature, Co2 sensors are used to measure the quality of water continuously. In addition to quality parameters, toxic chemicals are also being monitored with the aid of the MQ-9 sensor. Nowadays, it was amended to monitor the water bodies to continue to have good health for all forms of life in the world and to balance the ecological system in the biosphere. In this work, the sensors are connected to the NodeMCU microcontroller that it transmits the sensed data to the cloud. Furthermore, the stored data in the cloud can be retrieved and used for further analysis using deep learning mechanisms.

III. CURRENT QUALITY-RELATED PROBLEMS OF WATER BODIES

Good water quality is one of the most primary factors considering the health of every living thing in the biosphere and to the aquatic ecosystem [24]. At present, due to the unexpected growth of industries water and water bodies get spoiled and affected because of industrial wastage in various distribution networks across the globe. The nuclear reactor wastage affects the sea and aquatic-based living things. When human beings consume those seafood, indirectly health is getting affected. Use of hazardous chemicals in manufacturing industries and agriculture cause severe water pollution as they are directly let into nearby rivers, lakes, and ponds without getting treated to remove harmful toxins and compounds. Increasing water pollution badly affects marine life and their habitats. Poor people who do not have access to clean drinking water are forced to drink untreated water which makes them prone to water- related disease which affects their health. The accelerated evaporation of ponds is due to anthropogenic actions such as sewage disposal, and fertilizer run-off from agricultural lands. At a certain level polluted water can be dangerous to crops and reduce the fertility of the soil, thus harming the overall agricultural sector and the country as well [28]. Water-bodies and the nearby wetlands are affected and damaged due to the following factors:

Urbanization: Wetlands near urban centers are under increasing developmental pressure for residential, industrial and commercial facilities. Urban wetlands are essential for saving public water supplies.

Anthropogenic activities: Because of spontaneous urban and horticultural advancement, enterprises, street development, impoundment, asset extraction and dig transfer, wetlands have been depleted and changed, causing significant monetary and natural misfortunes in the long haul.

Agricultural activities: Following the Green Revolution of the 1970s, tremendous stretches of wetlands have been changed over to paddy fields. Development of countless, waterways and dams to accommodate the water system fundamentally adjusted the hydrology of the related wetlands.

Hydrologic activities: Development of waterways and preoccupation of streams and waterways to transport water to bring down bone-dry areas for water system has adjusted the waste example and essentially corrupted the wetlands of the locale.

Deforestation: Removal of vegetation in the catchments leads to soil erosion and siltation.

Pollution: Unhindered dumping of sewage and lethal synthetic compounds from ventures has contaminated numerous freshwater wetlands.

Climate change: Expanded air temperature, moves in precipitation, expanded recurrence of tempests, dry spells, and surges, expanded environmental carbon dioxide focus and ocean level ascent could likewise influence wetlands.

Introduced species: Wetlands are undermined by intriguing presented plant species, for example, water hyacinth and Salvinia. They stop up conduits and contend with local vegetation.

IV. RELATED WORK

Fiona Regan *et al.* have discussed a smart quality monitoring system in determining the data to be sent wirelessly. Fiona Regan *et al.* have proposed an idea of achieving the target by collecting the data from all the nodes wirelessly. It discusses the collection of water quality parameter data from smart sensors and sends the data to the device. In this system, the collected data are given to a remote server through the GPRS network. So, the user can view the data remotely. The sensors were present in water tap to measure whether the parameters of water. Fiona Regan *et al.* have stated that this system becomes highly scalable, faster and user-friendly. But some issues were found in the existing methodology that smart sensor becomes highly costly and any of the nodes fail in the network, then the path of data transmission will be lost.

Moreover, the size of the sensors is not reliable in the water tap. ZulhaniRasin *et al.* [26] have described the importance of a water quality monitoring system with Zigbee protocol based on Wireless Sensor Network. In this system, some sensors are connected to the Zigbee ZMN2405Hp module to measure the quality of water. It is implemented through WSN featuring high power transmission Zigbee based technology and also with IEEE 820.15.4 compatible transceiver. On the receiver side, Zigbee is connected to the Personal Computer that shows the GUI of the circuit. The high power Zigbee is used in this system and it can be applied for small area network. Data storage in the base station is necessary. ZulhaniRasin *et al*[26] have found some issues in the existing methodology in measuring the presence of gas present inside the water and water bodies.

NazleeniSamihaHaron *et al.* [15] have proposed an idea in developing a remote water quality monitoring system using wireless sensors for the elimination of cost consuming jobs of manual monitoring. The proposed work mainly focuses on the aquaculture for prawn farming. The measured values are collected by the data kit which sends the data to the processing unit through GSM modem. NazleeniSamihaHaron *et al*[15] have focused on monitoring the pH, temperature and dissolved oxygen in water. EZ430-RF2500 is the hardware module used which, consists of two parts one is the end device and another is an access point. The data from different sensors are monitored in the data processing unit and continuously compared with the constant parameter values. With the help of GSM modem whenever the sensor value crosses the threshold parameter value, then an alert message is sent to the farmer. If the water doesn't meet its quality parameter value, then, an alert signal is connected to the buzzer. In the proposed work,mobile phone is required for testing purposes and the phone act as the client. The proposed system [15] is more efficient in monitoring the prawn pond in aquaculture. NazleeniSamihaHaron *et al* [15] have found that is not suitable for long-distance and also it work for only single unit of the water source. Without mobile phone, the farmer won't receive an alert message in case of the unavailability of phones. If the phone gets damaged, then it would become a major problem with this system.

Dong He *et al.*[3]have discussed the water quality monitoring system based on Wireless Sensor Network (WSN). Dong He *et al*have proposed an idea to monitor the water quality based on WSN using the wireless network and remote data center. WSN collects the data about the quality of water from different regions and transfers the data to a remote data center with the help of GPRS DTU, which is built upon the TCP/IP protocol used for data transmission. In the proposed system the WSN is built on Zigbee protocol, it is mainly used for personal area networks and in a peer-to-peer network and so the transmission is very high. According to the function, the nodes of WSN are divided into three parts: coordinator, router, terminal. The responsibility of the coordinator is to receive and to transfer the data to GPRS DTU. Router node usually has no independent function of collection, it will transfer data from the terminal node to the coordinator node. Finally, the terminal node has different sensor modules like pH module, Pollutant levels, temperature, turbidity and so it will collect and transmit the data. With the help of the data collected from the data center is analyzed and used for further processing. This system can be used for the long term because it is stable and real-time water quality monitoring. However, this method isn't a cost-effective solution for a large area.

KulkarniAmruta *et al.*[10] proposed an idea of developing a solar-powered water quality monitoring system based on wireless sensor networks. In this system, KulkarniAmruta*et al* mainly focused on quality parameters like pH, oxygen level and turbidity through WSN technology that has been powered using a solar panel. In the proposed work, the simulation work was done to analyze the quality parameters for quality control with VB and MATLAB to measure the graphical and numerical record. In this system, the nodes collect the data from different wireless senor and transfer the data to the base station. With Zigbee protocol, the nodes can transfer the measured data to the base station that is powered by the solar panel. With the help of the solar panel, the system continuously gets power source and becomes more efficient. The system is expensive as well as, if the solar panel cannot be charged or got damaged because of any environment threats then the system will stop working.

V. SMART WATER QUALITY SYSTEM COMPONENTS

The Smart Water quality system includes three steps, namely, (i) Real-time data acquisition (ii) Communication Interface (iii) Wireless Sensor Node

Real-time data Acquisition

The real-time data Acquisition consists of the database for data aggregation from the wireless sensor node and data analyzer for processing the sensor data and provide feedback on the acquired data including alert message, warning signal, and contamination reports. The water quality analyze process is automated through a cloud server from reliable and remote monitoring.

Communication Interface

Communication Interface plays a major role in automation and process monitoring. The chosen embedded controller is built with an IoT module for such hostile environmental measurements since it requires larger bandwidth and an affordable data rate for real-time monitoring.

Wireless Sensor Node

The sensor node comprises the wireless module, controller and battery encapsulated in a watertight container. The container design as a floating buoy supports a hassle-free deployment and diverse extension. The floating buoy projected above the water surface level to acquire data and establish communication network with other neighboring nodes. The sensors are placed beneath the surface of the buoy to analyze the water bodies. The data are collected in a cluster header and communicated to the cloud server database using IP protocol is explained in figure-1.

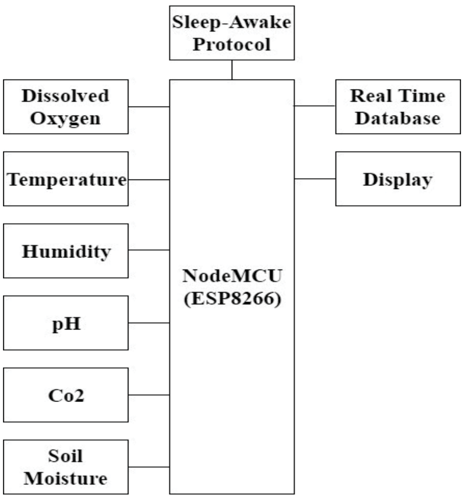

Figure-1: Block diagram Buoy System

Development of Buoy System

The buoy system is a generic and integrated with sensors for monitoring various water quality parameters such as seawater temperature, salinity, water level, and dissolved oxygen. The monitoring of physical and biochemical parameters for understanding the reason of change in the water quality, temperature, salinity and dissolved oxygen content in water is chosen as the initial parameters to monitor. The measurements are taken at different surfaces of the water bodies by rowing the buoy. The buoy is built with a floating substrate surrounded by air-filled balls, which is shown in figure-2. The wireless module placed on the buoy substrate supports a continuous collection of data and biochemical parameters from the sensors to the cluster header.

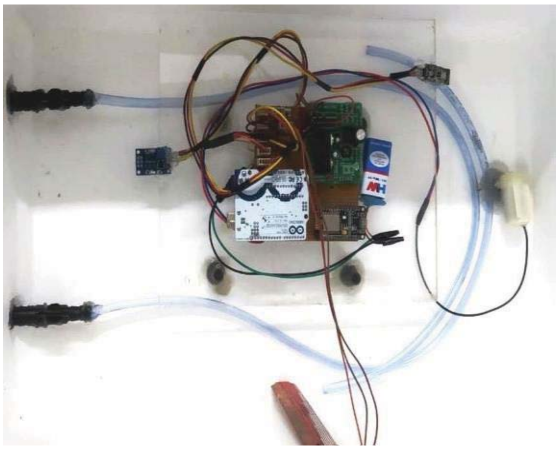

Figure-2: Water Quality Analyser

The wireless nodes are adapted with sleep and awake mechanism to reduce the power consumption and increase the network lifetime. The buoy is thermo coal substrate (150mmx450mm) surrounded with air-filled balls, (20mm diameter) tied along the walls of the buoy. This composition ensures that the buoyed weight, approximately 300gm, floats over the surface and distribute the load on the water surface equally.

VI. PROPOSED METHODOLOGY

The data acquisition framework is designed for the project is flexible and enables the user to access the data without any time delay in the receiver side. The framework is proposed with three layers, namely, monitoring and control layer, decision layer and data acquisition layer is shown in figure-3.

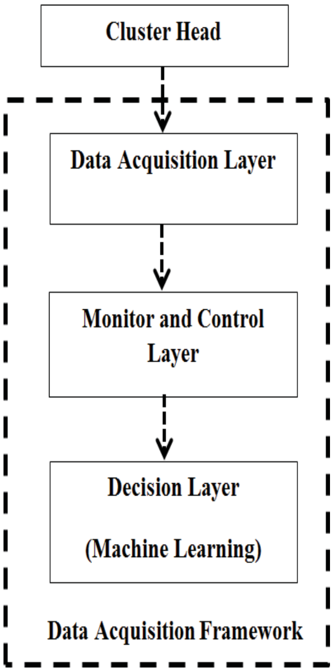

Figure-3: Data Acquisition Framework

The data acquisition layer, mainly used for acquiring data from the cluster head deployed in the water body. The cluster header collects all the information from the sensor in the network (figure-4) and processes the recent changes occurring in the sensor by comparing the data fetched in the previous cycle. The change in the data is sent to the server reducing the packet size and power consumption of the header node.

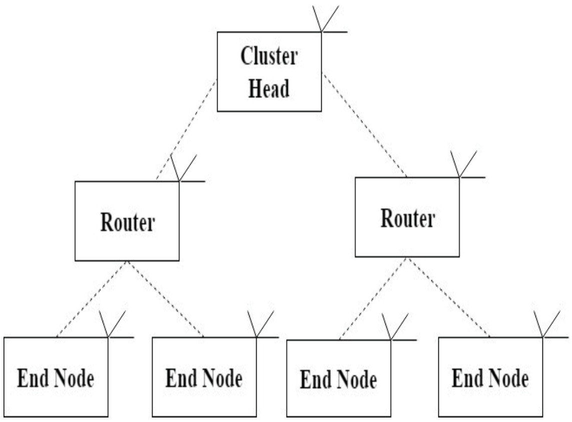

Figure4: Node's Cluster Head Architecture

The decision layer, diagnose the acquired data and compare it with the existing data. The changes are noticed for every hour in a day, the changes in the sensor value are reflected in the real-time database. The Smart water algorithm allows storing only if a significant change exists in the received data, this could effectively reduce the size of the database.

The water quality gets assessed in the monitoring and control layer where the data is available for the user for analysis and provides complete feedback on the sensor data. The user can get access and control over the smart water data acquisition.

Knowledge-Based Process Modelling

The water quality of the river is acquired from the Tamil Nadu Water and Drainage Board (TWAD) for analysis and the threshold values are trained using a machine learning algorithm. The instances are selected from a database of TWAD on 2016 statistics on the river sample content from worst to least contamination. The system is trained with all parameters with five different water classes Type-I, Type-II, Type-III, Type-IV and Type-V for predicting the samples collected as data from different sensors. The level of contamination is further regularized and the table of data is used for training and 30 percentage of data is used for testing the sample data accuracy. Total 1000 of the sample are regularized and trained and tested using the machine learning algorithm. The real-time data are correlated using the existing type and the appropriate type is displayed in the GUI.

VII. RESULTS AND DISCUSSION

The performance of the sensor node is stored in the real-time database and live feed is monitored using smart water quality assessment and decision system. The water quality is analyzed using the live feed of data and the system indicates the status as normal, warning and abnormal based on the sensor value correlated against the threshold mentioned in table -1.

Table-1: Correlations coefficient and Contamination indicators

Temperature	**Humidity**	**Co2 Emission**	**pH**	**Dissolved Oxygen**	**Soil Moisture**
0.385	0.253	0.532	0.615	1.000	-0.424
-0.706	0.353	**-0.784**	**-0.978**	-0.453	**0.854**
0.157	0.526	0.614	-0.018	-0.028	0.094
1.000	**-0.813**	0.688	0.623	0.375	**-0.723**
0.677	0.449	**-0.743**	1.000	0.651	**-0.783**
-0.719	1.000	1.000	**-0.792**	-0.435	1.000
0.168	**-0.792**	0.567	0.267	-0.069	-0.389
0.448	0.178	0.732	0.564	0.313	1.000
-0.712	1.000	**-0.922**	0.672	0.432	-0.394
0.162	0.554	1.000	**-0.876**	**-0.731**	**-0.742**
0.698	**-0.832**	0.618	0.476	-0.049	0.056
1.000	0.723	0.390	1.000	0.476	0.061

The figure-2 is a model of the smart water quality assessment and decision system capable of storing the data in the local server and generates reports accordingly. The sensor transmission delay, network orientation, battery power are shown at the bottom of the GUI. The possible status of water along with chemical and pollutant content is shown in the monitoring pane. The colors are used to represent the level of contamination where the text indicated with blue-normal, yellow-warning and red for over contamination. The water assessment sample results a shown in the table are collected from the river surface with six nodes placed at a distance of 300m approximately from each other spanning 1.8 Km deployed near to the possible area of contamination.

The water contamination in water bodies is determined by the data aggregated from different sensors which are deployed. The contamination is calculated by estimating the correlation value between multiple sensors using the correlation coefficient(),which is given by

$$r_{xy} = \frac{\sum_{i-1}^{n}(x-\bar{x})(y-\bar{y})}{\sqrt{\sum_{i-1}^{n}(x-\bar{x})^2}\ \sqrt{\sum_{i-1}^{n}(y-\bar{y})^2}} \quad (1)$$

X and Y refer to two separate water quality sensors. $x, y\ \epsilon\ \{pH, ORP, UV, \ldots\}$. $\bar{x}$ and $\bar{y}$ stands for mathematical expectation. The number of data or window size is given by n. The window size is the number of past observations used to calculate the correlation coefficient. For each sensor, a new observation enters the sliding window at every time step t and the oldest observation exits in queue.

$$\mathrm{C_i} = 0 \text{ if} \left|\mathrm{r_{xy}}\right| < \mathrm{threshold_{indicator}}\ or \quad (2)$$

$$\mathrm{C_i} = 1 \text{ if } \mathrm{threshold_{indicator}} \leq \left|r_{xy}\right| < 1 \quad (3)$$

The value of Rxy is between -1 and 1. The correlation indicator Ci is calculated using

$$\sum_{x}^{\forall}\sum_{x}^{\forall}\sum C_{i\ \geq threshold_{alarm}}\ x \neq y, x, y\ \epsilon\ \{pH, ORP, UV, \ldots\} \quad (4)$$

\

$$\sum_{x}^{\forall}\sum_{x}^{\forall}\sum C_{i\ \geq threshold_{alarm}}\ x \neq y, x, y\ \epsilon\ \{pH, ORP, UV, \ldots\} \quad (5)$$

The results for measuring the water quality parameters are illustrated in the figure 4. The different values such as Humidity, Temperature, and carbon dioxide are measured using different sensors. The results are being displayed in the serial monitor in the PC or Laptop itself. Finally the values to measure the water quality parameter in real time have been achieved.

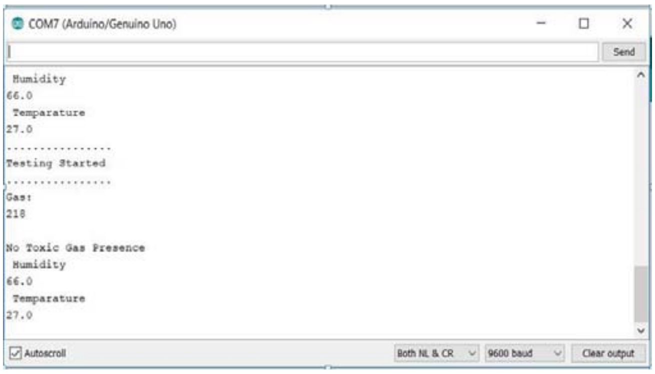

Figure-5: Results Measured in Serial Monitor

The Sensed values like Temperature, Humidity, Co2, pH, Dissolved oxygen and Soil moisture from different sensors are measured and transmitted to firebase cloud with the help of the ESP8266 with in-built Wi-Fi protocol. The Figure 5 shows the values are stored in the firebase. These values are stored as Real-time database in the cloud. The sensed data's are easily moved to the cloud using ESP8266. In the Firebase cloud the database has to be created and the authorization key, host name of the database has to be attached with the coding. Whenever the Sensor sense the data then the data will be automatically stored in the firebase cloud storage in the real time database.

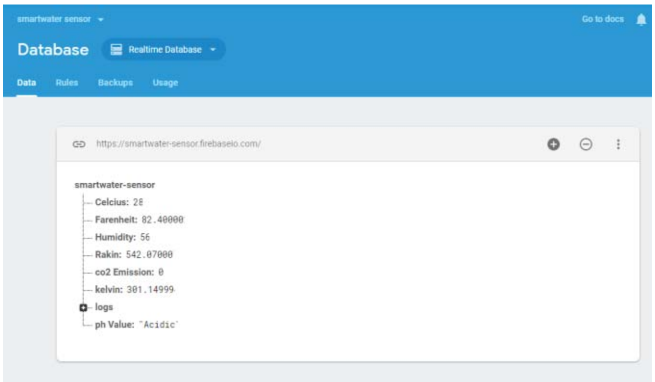

Figure-6: Values Stored in Firebase Cloud

VIII. CONCLUSION

The water contaminations determined by the sensors are eco-friendly and utilization of chemical reagent for evaluation is avoided. The dissolved oxygen, temperature, water moisture, and pH sensors build on the floating buoy were reliable and easier for expansion throughout the water resource. Moreover, the sensor supports continuous monitoring and maintains network life for about 90-120days based on the sleep-wake mechanism cycles. The cluster head protocol suited well for data transmission and single end traffic improves network stability. The buoy is self-balanced over the water surface ensuring the sensor portion completely sinks and antenna heads are available for communication. Moreover, the buoy eliminates the risk of sensor getting damaged and maintenance cost is lower than any other traditional models.

REFERENCES

[1] Jaytti Bhatt, Jignesh Patoliya,, "IoT Based Water Quality Monitoring System", vol. 4, no. 4, pp. 762-766, 2016.

[2] Geetha S, Gouthami S, "Internet of Things Enabled Real Time water Quality Monitoring System", Smart Water International Journal for aqua – Smart ICT for Water, vol. 2, no.1, pp. 3-11, 2017.

[3] Kumar RK, Mohan MC, Vengatesh pandiyan s, Kumar MM, Eswaran R, "Solar Based Advanced Water Quality Monitoring System Using Wireless Sensor Network', International Journal of Science Engineering and Technology Research, vol. 3, no.3, pp. 385-389, 2014.

[4] Goib Wiranto, Grace A, Mambu, Hiskia, I Dewa Putu Hermida, Slamet Widodo, "Design of Online Data Measurement and Automatic Sampling System for Continuous Water Quality Monitoring", Proceedings of 2015 IEEE International Conference on Mechatronics and Automation, pp. 2331-2335, 2015.

[5] Zulhani Rasin, Mohd Rizal Abdullah,"Water Quality Monitoring System Using Zigbee Based Wireless Sensor Network", International Journal of Engineering and Technology, vol. 9, no. 10, pp. 14-18, 2009.

[6] Kroll, D., King, K., Laboratory and flow loop validation and testing of the operational effectiveness of an online security platform for the water distribution system in Proceedings of 8th Annual Water Distribution Systems Analysis Symposium pp. 1-16, 2006.

[7] Perelman, L., Arad, J., Housh, M., Ostfeld, A., "Event detection in water distribution systems from multivariate water quality time series", Environmental Science & Technology vol. 46, no. 15, pp. 822-8219, 2012.

[8] Arad, J., Housh, M., Perelman, L., Ostfeld, A., "A dynamic thresholds scheme for contaminant event detection in water distribution Systems Water Research", vol. 47, no. 5, pp. 1899-1908, 2013.

[9] Y. L. Xiong, "Application research of biological monitoring technology in environmental monitoring", *Resource. Economization Environ. Protection*, vol. 12, no. 6 pp. 93-98, 2016.

[10] L. Wang, "Biological monitoring and application in environmental monitoring", *Technology Innovations. Application.* Vol. 8, no. 1, pp. 181, 2017.

[11] Z. H. Song, Q. W. Wang, "Study on joint toxicity and biological early warning of Cu2+ Cd2+ and Cr6+ Using Zebrafish", *Asian J. Ecotoxicol.*, vol. 6, no. 4, pp. 361-366, 2011.

[12] A. H. Mirza, S. Cosan, "Computer network intrusion detection using sequential LSTM neural networks autoencoders", *Proceedings in IEEE Signal Process Communication. Application Conference (SIU)*, pp. 1-4, May 2018.

[13] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, Y. Cayirci, "Wireless Sensor Networks: A Survey", *Computer Networks*, vol. 38, pp. 393-422, 2002.

[14] Chen et al., "A Vision of loT: Applications Challenges and Opportunities With China Perspective", *IEEE Internet of Things Journal*, vol. 1, no. 4, pp. 349-359, 2014.

[15] M. Rizzello, C. Distante, P. Siciliano, "A Standard Interface for Multisensor Systems", *Sensors for Environmental Control*, pp. 224-228, 2003.

[16] "Surface Water Standards & Guidance" in U.S. EPA., U.S. Environmental Protection Agency, 2012.

[17] Philo Juang et al., "Energy-efficient Computing for Wildlife Tracking: Design Tradeoffs and Early Experiences with ZebraNet", Architectural Support for Programming Languages and Operating Systems, vol. 37, no. 10, pp. 96-107*10,* 2014.

[18] J. Downing, "Turbidity monitoring" in Environmental Instrumentation and Analysis Handbook, Hoboken, pp. 511-546, 2005.

[19] V. Raut, S. Shelke, "Wireless acquisition system for water quality monitoring", *Proc. Conference on Advance in Signal (CASP)*, pp. 9-11, 2016.

[20] H. Liu et al., "Generalized weighted ratio method for accurate turbidity measurement over a wide range", *Opt. Exp.*, vol. 23, no. 25, pp. 32703-32717, 2015.